RELEASE AND CONSUMPTION OF OXYGEN BY A PHYTOPLANKTON DOMINATED COMMUNITY OF A EUTROPHIC LOWLAND RIVER

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1 Introduction

Most studies of stream ecosystem metabolism have concentrated on streams and rivers, where macrophytes and/or microphytobenthos determine autotrophic activity (e.g. BUTCHER et al. 1930, ODUM 1957, EDWARDS & OWENS 1962, KELLY et al. 1974, THYSSEN & KELLY 1987). The objective of this study was to measure the dissolved oxygen concentration (DO) and to estimate primary production (P) and community respiration (R) in a eutrophic lowland river, where phytoplankton dominates the autotrophic part of the community. The variability of DO, P and R was investigated over different time scales, including hours, variations from day to day, and seasons.

2 Study Area

The study site was located in Freienbrink on a lotic section of the lower River Spree near Berlin, Germany (5222'N, and 1348'E, Fig. 1). The climate of the catchment area is humid-temperate with continental influence (Precipitation 500 to 600 mm/a). The population is about 820 000. Nearly one half of the lower catchment area is covered by forests, 12 % are urban areas, and the rest is mainly farmland. The river length above the probe site is about 320 km, the area about 6330 km², the slope 20 km upstream 0.2 m/km and 100 km upstream 0.1 m/km. 22 km upstream from Freienbrink an artificial channel takes about one half of the water. The flow is regulated and varies only slightly (MNQ 10, MQ 17, and MHQ 30 m^3/s 1976-85). While MQ the channel depth averages 1.5 m, itswidth 20 to 25 m. Flow velocity varies between 0.4 and 1 m/s, the Secchi depth between 0.4 and 2.0 m. The water is rich in nutrients (DIP 0.01 - 0.04 mgP/l, DIN 0.4 - 4.7 mgN/l). In spring pennate and centric diatoms, and *Limnothrix redekei* dominate. During summer and fall blue greens of the genera Planktothrix and Aphanizomenon, Actinocyclus, and diatoms of the genus Stephanodiscus dominate (KÖHLER 1993). Phytoplankton biomass averages 28 mg/l FW over the whole growing season, and seston 24 mg/l DW.

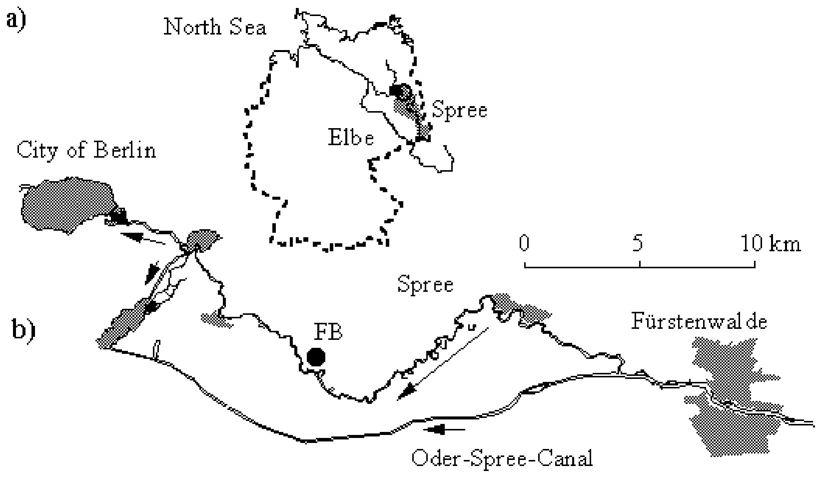

Fig. 1 a) Map of Germany and the location of the River Spree catchment area. b) River Spree between Fürstenwalde and Berlin. It is shown the monitoring station (FB), the flowing direction and relative speed (arrows).

3 Method

Primary production (P) and respiration (R) of the river community was estimated by a modification of ODUM's (1956) single station oxygen time curve analysis. Nearly continuous records of dissolved oxygen concentration (DO), temperature (T), water level (L), and hourly integrals of global radiation (I_o) were obtained from March to November 1989 and from May to August 1992 using automated data logging units. DO, T, and L were recorded every minute (Fig. 2). Hourly averages were used for the analysis after correction of obvious runaways, e.g. the minutes of DO-probe calibration or cleaning (Fig. 3). To calculate P and R from the oxygen mass balance equation it was necessary to estimate the reaeration coefficient (K). This was carried out according to WOLF (1974), where the value of K depends on the flowing velocity (V), the depth (H) of the channel, and the roughness of the river bed (M, for Manning-coefficient):

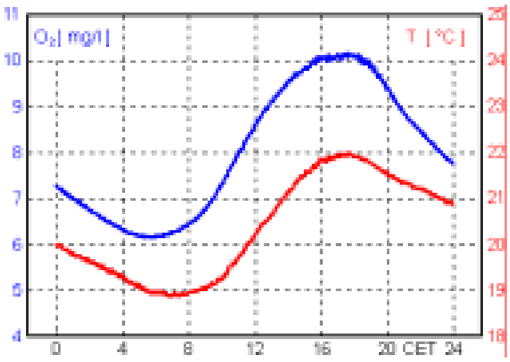

Fig. 2 DO concentration and water temperature in the River Spree. The resolution is one minute, the date is 07/29/92.

$$K(20°C) = (3 + 40/M) * V/H^2 + H/2 \qquad (1)$$

M was set to 31. H was averaged from 220 upstream depth profiles which were measured by water authorities in steps of 100 m. Stream velocity was measured with fluorescine dye and drifting buoyes to find a relationship to water level. The contuinously measured water level was used to calculate hourly values of H and V. Temperature dependence of K was calculated by

$$K(t) = K(20°C) * C^{(T-20)} \qquad (2)$$

assuming C is 1.024 (TSIVOGLOU et al. 1976). In order to investigate the functional relationship between P and iradiance (I) an hourly integral light value for the water column was calculated using

$$I = C * I_o/E * (1 - \exp(-EH))/H \qquad (3),$$

where I_o is the global radiation measured about 10 km away from the station, and E the light extinction of the river water. C is a coefficient, which was set to 0.4 to consider reflexion and the screening effect of bank vegetation (20 %), and the photosynthetic active radiation was assumed to be 50 % of I_o.

4 Results

The measured DO concentration shows a distinct seasonal pattern with increasing supersaturation during the spring phytoplankton bloom, a sharp drop to a clear water stage in June with lowest values, varying values in summer (mostly below saturation) declining in September, and growing DO nearly reaching saturation in November.

During spring bloom the mean oxygen concentration, the (super-) saturation, and the amplitudes of the daily variation had maximum values within the seasonal cycle.

The clear water stage regularly sets in during the last decade of May. In at least half of the past 20 years it was possible to detect a clear water stage. In 1992 the clear water continued about 5 weeks. Later, the concentration of planktonic algae, mainly blue-greens, rose to summer bloom values. In contrast to the very sharp decline of DO concentration within three days this year, in 1989 it extended 5 weeks to reach the minimum DO concentration. Moreover, only one week later the growing summer bloom caused a rapid increase in the DO concentration up to the typical summer bloom values.

The DO concentration depends on temperature, photosynthetic release (input), chemical and biochemical reduction, and exchange with the atmosphere. Based on the model explained above, estimations of daily integrals of P, R, and net daily metabolism are shown in Fig. 4, and mean, minimum and maximum values in Tab.1. In 1989 P averaged 3.1, R 4.2 mg/(l*d), and P/R was 0.75 for the whole season.

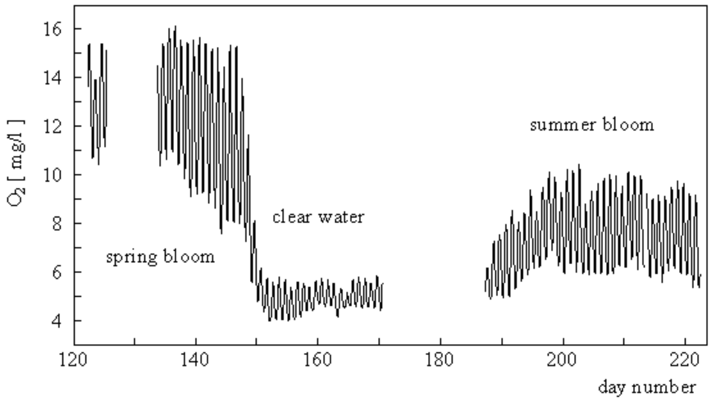

Fig. 3 DO concentration in the River Spree from 05/02/92 to 08/10/92. The resolution is one hour.

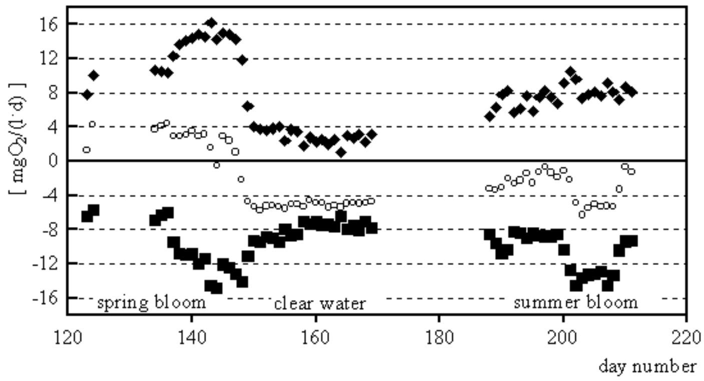

Fig. 4 Gross production (triangles), net community metabolism (circles), and community respiration (squares) in the River Spree from 05/03/92 to 07/31/92 (respiration multiplied by -1).

Tab. 1: Means, minima, and maxima of daily integrals of net community metabolism (NCM), gross primary production (P), and community respiration (R) of the River Spree from 05/02/92 to 07/31/92 in $gO_2/(m^2d)$.

period (day numbers)		NCM	P	R
spring bloom (123 - 146)	AVG	4,10	18,60	14,50
	MIN	-0,80	11,20	8,20
	MAX	6,40	23,40	21,30
clear water (150 - 169)	AVG	-6,40	3,60	10,00
	MIN	-7,20	1,30	8,10
	MAX	-5,80	5,10	11,90
summer bloom (188 - 211)	AVG	-3,50	8,80	12,30
	MIN	-7,20	6,10	9,50
	MAX	-0,80	12,00	16,70

The most important factor determining P is the algal concentration of the river water.

Because the seston in the River Spree mainly consists of phytoplankton and its remains, Tab.2 gives an idea of the proportions between the seasons. Despite pronounced irregular variations of the global radiation (I_o) between 3 and 25 $MJ/(m^2d)$ in 1992, P follows these variations only slightly. Nutrients are commonly available in excess and rarely inhibit P.
The factor chiefly determining R is seston concentration, but respiration by benthic components of the community may be very important. Comparison of P and R measured in bottles (KÖHLER 1993) to results of the open water method indicate that P is mainly supported by plankton, while planktonic R was only 20% of the whole community respiration in summer bloom. Direct measurements of benthic activity

is in preparation.

Tab. 2: Means, minima, and maxima of water temperature, flow, and seston dry weight estimations of the River Spree from 5/2/92 to 7/31/92.

period (day numbers)		T °C	Q m^3/s	seston mgDW/l
spring bloom (123 - 146)	AVG	17,10	12,00	35,3[1)]
	MIN	13,40	10,10	34,8[1)]
	MAX	20,20	16,10	36,1[1)]
clear water (150 - 169)	AVG	20,00	8,60	11,00
	MIN	18,20	7,70	9,70
	MAX	21,10	9,50	15,00
summer bloom (188 - 211)	AVG	20,50	6,60	19,80
	MIN	19,20	5,90	16,50
	MAX	21,40	7,20	22,80

[1)] number of observations only two, otherwise (9) 15 to 24

From Fig. 5 it becomes evident that the large seasonal changes in P/R are caused mainly by changes in P, while R remains relatively constant. In comparison to results from other rivers obtained with open water methods, the seasonal River Spree P- and P/R-values cover a large part of the entire range hitherto measured.

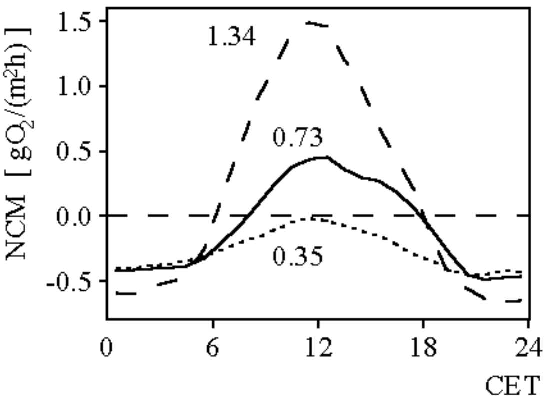

Fig. 5 Daily course of net community metabolism rate and P/R-values of different markedly distinguishable periods in 1992.

Monthly means of oxygen data from other rivers prove the pattern of seasonal changes of DO concentration observed in River Spree are common in eutrophic lowland rivers in Germany (Fig. 6a). Compared to River Spree, the DO concentration in Warnow and Peene are even higher during spring bloom, the clear water stage finds a deeper expression in low DO values, and the summer bloom peakshigher. In contrast to these medium sized rivers, the long term monthly means of the large rivers Rhine, Elbe, and Main do not show distinct seasonal peaks or drops (Fig. 6b), despite of high concentrations of phytoplankton. Probably, the relatively great depth and high turbidity prevent a higher influence of phytoplankton on the oxygen relationships of large rivers. The distance to the saturation DO concentration is nearly constant over the entire year. The high distance of the River Elbe values is mainly caused by the extraordinary high waste water load.

River Löcknitz does not count as a large river, but DO values follow the same pattern. This river is a small eutrophic lowland river (annual mean flow about 0.7 m^3/s), too, but it is shaded by dense bank vegetation, and phytoplankton growth remains on a low level. The low DO concentration may be caused by high benthic respiration rates of emerse aquatic vegetation, roots of trees, and attached zoobenthos and bacteria.

5 Summary

From March to Novemer 1989 and from May to August 1992 dissolved oxygen concentration (DO), water temperature and flow was measured continuously in the River Spree near above Berlin. Physiographic conditions were very constant for 20 km before the station. Neither significant tributries nor waste water discharges contribute to the flow or water quality of the highly eutrophicated, free flowing river strech. The autotrophic community was dominated by planktonic blue-greens and diatoms (KÖHLER 1993, see this brochure).

Primary production (P) and respiration (R) of the river community was estimated by a modification of ODUM's (1956) single station oxygen time curve analysis.

DO showed a predictable seasonal pattern with increasing supersaturation during the spring phytoplankton bloom, a sharp drop to a clear water stage in June with lowest values, varying values in summer (mostly below saturation) declining in September, and growing DO nearly reaching saturation in November. Other eutrophic lowland rivers in Germany behave similar.

In 1989 P averaged 3.1, R 4.2 mg/(l*d), and P/R was 0.75 during the whole growing season. The distinct seasonal changes of P and P/R mainly depend on changes in phytoplankton concentration, whereas R is mainly controlled by benthic community respiration.

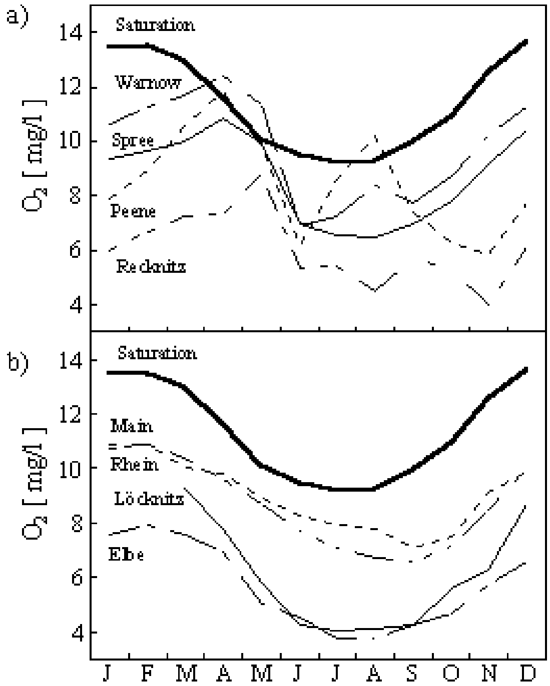

Fig. 6 DO concentration in different German rivers. The original data were published by several water authorities. The figures are monthly averages: Spree 1976 - 90, Warnow, Peene, and Recknitz 1987 - 90, Rhine Bimmen/Lobith 1982 - 90, Main 1982 - 90, Elbe Schnackenburg 1982 - 90, Löcknitz 1990 - 91 (IGB values).

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